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PASGT Helmet Test: An Example of Effective Intra-Government Testing Collaboration

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The Office of the Director of Operational Test and Evaluation requested Army Test and Evaluation Command and Army Research Laboratory Survivability/Lethality Analysis Directorate support to plan, execute, and report on a test program to assess ballistic performance of Kevlar helmets. The effort was a result of a Department of Justice investigation into a primary contractor for Kevlar helmets. That investigation identified alleged noncompliance with manufacturing requirements specified in the Kevlar helmet military specification, which could result in decreased personnel protection. Helmets tested during this effort were selected from a population of items manufactured during the spanned Department of Justice investigation (1987–2006). An initial test strategy was developed with Office of the Director of Operational Test and Evaluation, Army Test and Evaluation Command, and Army Research Laboratory Survivability/Lethality Analysis Directorate to characterize the helmet performance using ballistic v_{50} test procedures.

Key words: Ballistic limit (v_{50}); intra-government collaboration; Kevlar helmet performance; military specifications; testing.

This effort required extensive collaboration and cooperation from several agencies and organizations within the Department of Defense (DoD). Additional complexity arose due to the potential legal implications stemming from the Department of Justice (DOJ) investigation. Within the DoD, the following agencies and organizations were involved in the effort.

Office Secretary of Defense (OSD)

- Executive Secretariat,
- Under Secretary of Defense for Acquisition, Technology & Logistics,
- Deputy Under Secretary of Defense for Logistics and Material Readiness (DUSD [L&MR]),
- Director, Operational Test & Evaluation (DOT&E),
- Defense Logistics Agency (DLA),
- Defense Supply Center–Philadelphia (DSC-P).

U.S. Army

- Army Test and Evaluation Command (ATEC),
- Army Evaluation Center,
- Developmental Test Command,
- Aberdeen Test Center (ATC),
- Army Research Labs–Survivability/Lethality Analysis Directorate (ARL-SLAD),
- Program Executive Office Soldier (PEO Soldier).

U.S. Marine Corps

- Marine Corps System Command (MARCORSYSCOM).

The effort was initiated by the DOJ with an informal request to DoD addressed "To Whom It May Concern." Because the DOJ letter did not identify an agency, the request was circulated throughout DoD in an effort to identify the most appropriate agency to execute a response. The DOJ request was first given to PEO Soldier. PEO Soldier gave the letter to DOT&E, who then turned the DOJ letter over to the OSD General Counsel. OSD General Counsel contacted DOJ and requested the letter be rewritten and sent to the Secretary of the Army.

The Secretary of the Army then handed the DOJ request up to the OSD Executive Secretariat, who in turn named DUSD (L&MR) as the lead organization. DUSD (L&MR) tasking from OSD was to investigate the quantity of fielded Personnel Armor System for

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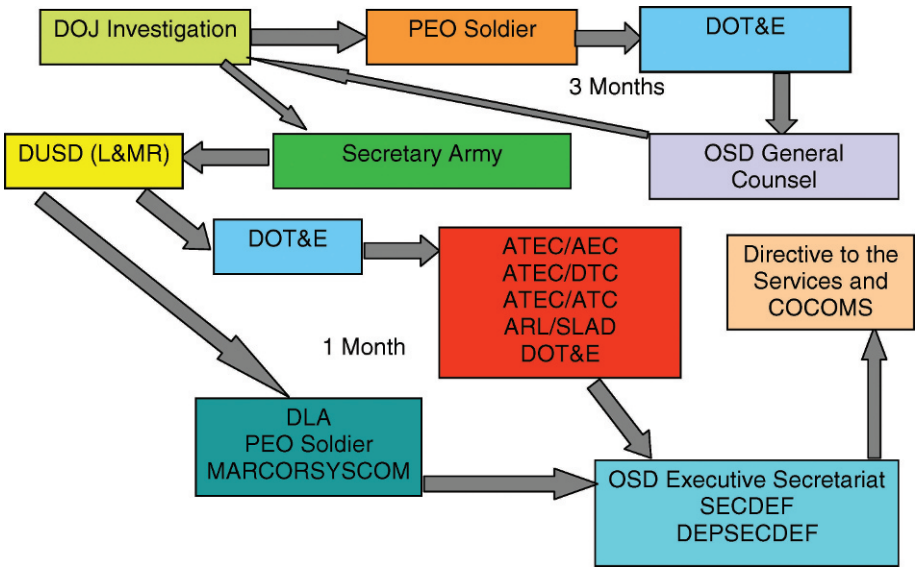


Figure 1. Intra-government testing and collaboration.

Ground Troops (PASGT) helmets, determine what services the PASGT helmet had, and develop a path forward (including the cost and logistics of replacing the PASGT helmets). The Honorable Jack Bell (DUSD [L&MR]) sent a letter to the Honorable Dr. Charles McQueary requesting DOT&E perform testing. DOT&E tasked ATEC and ARL-SLAD to execute a test and report back to DOT&E on the results. DOT&E then reported to the Secretary of Defense.

DUSD (L&MR) directed DLA to determine the PASGT helmet worldwide distribution and stockpile. DUSD (L&MR) requested that the information be prepared in the event that the PASGT helmet needed to be replaced with the Advance Combat Helmets (ACH) and Light Weight Helmets (LWH) in the event of an unfavorable test outcome. DLA designated DSC-P as lead logistics organization for that effort.

DLA contacted PEO Soldier and MARCORSYSCOM to determine the quantity of ACH and LWH in inventory and available for fielding. DSC-P also led the effort to acquire the necessary helmet test assets in various sizes and manufacturing years to represent the helmet population in question.

Figure 1 illustrates the time line and coordination that crossed agency boundaries to execute an effective and timely test. The coordination of the DOJ request took approximately 3 months, while the test was planned, executed, and reported on in 1 month.

Impact

The outcome of the test had the potential to impact the survivability of millions of U.S. and foreign service men and women. The purpose of the test was to determine if the alleged noncompliance with Kevlar manufacturing requirements resulted in a decrease in ballistic protection. The PASGT helmet was widely fielded to millions of U.S. and foreign service men and women. *Figure 2* illustrates the breakdown of PASGT use by service and foreign military.

In 2007, the PASGT helmet use by U.S. military Services in theater was as follows:

- Army: none,
- Navy: 2,568 in Iraq,
- Air Force: 6,768 in Iraq,
- Marines: none,
- approximately 29,000 issued to noncombat personnel.

At the time of the test in 2007, the PASGT helmet was protecting service men and women in formations alongside those wearing the ACH and LWH. The ACH and LWH are 21st-century helmets with superior technological advantage and were designed to complement the body armor now being used.

Test objective

The objective of the test program was to determine if the empirical estimates of the ballistic limit (v_{50}) met the requirement of 2,000 feet/second (MIL-H-44099A, para. 3.5.2) with a 95 percent confidence level for the PASGT helmet population in question.

Test

ARL-SLAD and ATC conducted testing simultaneously in order to increase the speed of the test and

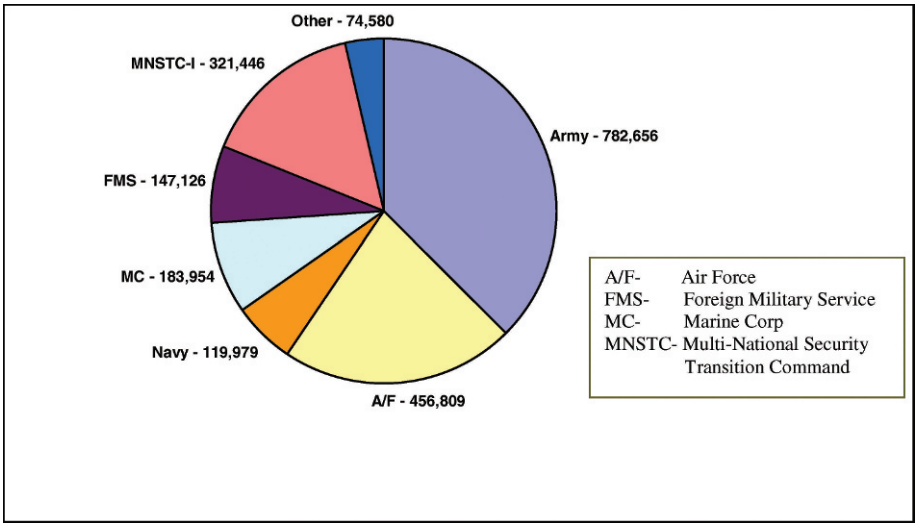


Figure 2. PASGT—total quantity demanded, FY89 to present.

reduce any potential biasing. Both facilities followed test protocols identified in military specifications MIL-H-44099A Helmet, Ground Troops and Parachutists dated 22 December 1986 and MIL-STD-662F, "V50 Ballistic Test for Armor" dated 18 December 1997. An industry standard gun barrel was used to launch the 17-grain fragment simulating projectile (FSP) where the striking velocity was recorded and yaw measured at or near target impact. Yaw card data was compared, post-shot, to a predetermined maximum 5-degree yaw template to ensure that the penetrator impacted the helmet at less than the 5-degree yaw requirement. The helmet was rigidly mounted to a stationary target fixture. Fair hit impact points were a minimum distance of 1.5 inches from each other, from holes, crease locations, or the edge of helmet. A complete penetration was one where any part of the FSP perforated a witness plate positioned inside the helmet, 2 inches from the impact point. *Figure 3* shows exterior and interior views of the impact locations for a tested helmet.

Helmets are manufactured in five sizes: X-Small, Small, Medium, Large, and X-Large. Test sample dates of manufacture are from 1987 to 2006, spanning the period of helmet production in question. Helmets were obtained from current inventory levels at the DLA and tested against criteria set forth in Military Specification MIL-H-44099A. The test samples included two manufacturing age groups (1987–1996 and 1997–2006) and five sizes (XS, S, M, L, XL). Based upon inventory received from DLA, ATEC and ARL determined the randomization and distribution of test samples. ATEC and ARL also made the assumption that the random sample received from inventory was representative of the PASGT helmet population in question.

For each helmet group, the v_{50} ballistic limit was determined using four series of the modified Langlie sequential firing procedure. For each helmet group, four series (10–15 shots per series) of the modified Langlie firing procedure were conducted. Size Small was not available for the older helmets; therefore, there were a total of 36 series. *Table 1* shows the total number of shots conducted by helmet size and year.

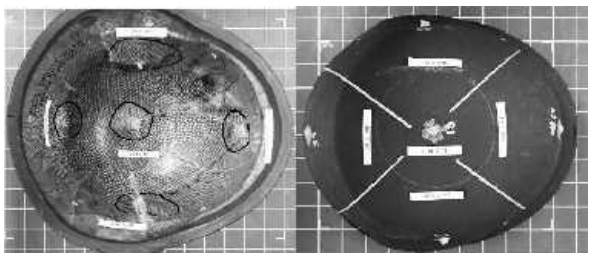


Figure 3. Exterior and interior views of a helmet after testing.

Table 1. Total number of shots conducted by helmet size and manufactured group.

Helmet size	Manufactured date		Shots per size
	1987–1991	2003	
X-Small	50	50	100
Small	N/A	58	58
Medium	43	52	95
Large	48	54	102
X-Large	60	50	110
Shots per manufactured group	201	264	465

Data collection

The modified Langlie sequential firing procedure is based on the Langlie method (DARCOM Pamphlet 706-103, 1983 and TOP 2-2-710) and was used to select velocities for obtaining estimates of the v_{50} ballistic limit. Several modifications were made to obtain velocities away from the mean to better estimate the entire response curve. A computer program was created to automate the procedure for each testing facility (ARL and ATC). The modified Langlie sequential firing procedure is listed below. The upper and lower projectile velocity limits (gates) were set at 200 feet/second from the postulated mean. All shots were conducted at zero degrees obliquity.

For each helmet, one shot was fired in each subdivision of the helmet as specified in MIL-H-44099A: the crown and four circumferential quadrants—front, back, left, and right. Therefore, to complete a v_{50} series, at least two or three helmets were required. In addition, four series of the sequential procedure were conducted for each helmet group. Each series acted independently, as if starting over.

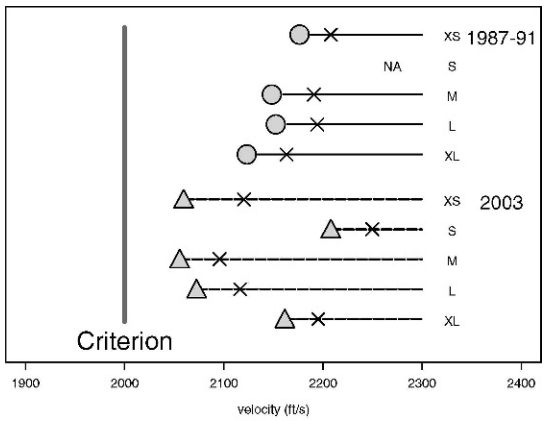
Testing contained the following for each series, with a minimum of 10 shots and maximum of 15:

- A zone of mixed results (at least one partial penetration has a higher velocity than a complete penetration). The size of the zone of mixed results is defined as the difference in velocity between the highest partial penetration and the lowest complete penetration.
- The average of the complete penetrations is larger than the average of the partial penetrations.
- The spread of the three highest partial penetrations and the three lowest complete penetrations is within 125 feet/second.
- Ensure that the data set contains values approximately ±66 feet/second from the v_{50} that is estimated from the three highest partial penetrations and three lowest complete penetrations.

Since all the data from four series were combined, there was always a zone of mixed results from which to get parameter estimates.

Analysis

Statistical hypothesis tests were used to analyze and compare the v_{50} data. Statistical hypothesis testing is a procedure that involves stating something to be tested, collecting evidence, and then making a decision as to whether the statement (null hypothesis) should be accepted as true, or rejected. To determine failure to accept or reject the null hypothesis (H_0), the probability values (*P* values) were evaluated.



X = V50
○ = 95% Lower Confidence Limit on V50 for 1987-91 age group
△ = 95% Lower Confidence Limit on V50 for 2003 age group

Figure 4. v_{50} and 95 percent lower confidence limits on the v_{50} compared with criterion of 2,000 feet/second.

If the *P* value is less than .05, the null hypothesis would be rejected with a statement that there is a significant difference between or among the v_{50}s. However, if the *P* value is greater than or equal to .05, the null hypothesis would fail to be rejected with a statement that there is not enough evidence in the data to determine that v_{50}s differ.

Results

Analysis of the test data showed that there was no significant statistical difference between the ARL-SLAD and ATC test facility data and between the year groups. Analysis did show a small statistical difference among the sizes in the 2003-year group. *Figure 4* shows the v_{50} for each size within each year group along with the 95 percent lower confidence limit (LCL). Each LCL is above the criterion of 2,000 feet/second. The sizes were combined (pooled) into one group with a v_{50} of 2,157 feet/second. The 1987–1991 sizes were not significantly different and their combined v_{50} is 2,187 feet/second.

Since the manufactured years were not significantly different, the data were combined to produce one v_{50} of 2,170 feet/second, and the 95 percent LCL on the v_{50} is 2,154 feet/second as shown in *Figure 5*. Therefore, if we repeatedly conducted this experiment (same sample size from the same population), and a confidence interval was calculated from each repetition, then 95 percent of these intervals should contain the population mean (v_{50}). There is a 95 percent confidence that our interval with a lower bound at 2,154 feet/second contains the true v_{50}.

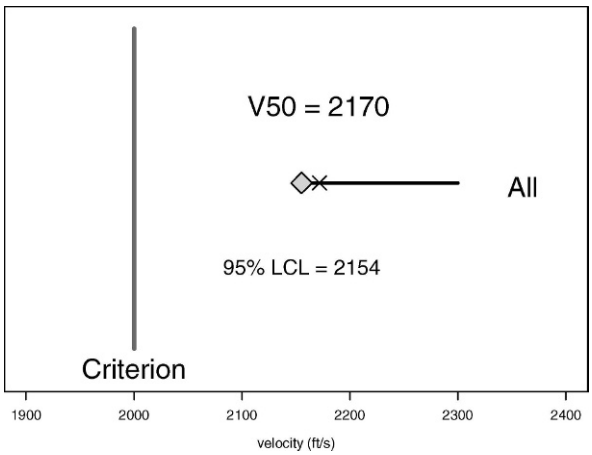


Figure 5. Combined v_{50} for all groups and sizes and the 95 percent lower confidence limit on v_{50}.

Test conclusion

Testing of PASGT helmets in five different sizes (XS, S, M, L, XL) from production years 1987–2003 produced an aggregate v_{50} at 2,170 feet/second and an LCL at 2,154 feet/second. The robustness of testing was sufficient to produce an aggregate v_{50} with 95 percent level of confidence for the population. There was some statistical variation among sizes for the 2003-year group; however, variations between groups were not significantly different, and v_{50}s could be aggregated into one summary result, still maintaining a 95 percent confidence level. As stand-alone size and year groups, all combinations exceeded the v_{50} requirement at the 95 percent confidence level. The helmets tested are in compliance with the MIL Specification MIL-H-44099A Helmet, Ground Troops and Parachutists.

Conclusion

Although the test results indicated the PASGT helmets were within specifications, Deputy Secretary of Defense recalled all PASGTs and directed the Services to immediately cross-level all personnel participating in operations in South West Asia to the ACH or LWH, thereby increasing the survivability of our forces. Consequently, the U.S. Services now have one uniform protection standard for troops operation in the same battle space. ❑

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